SPACE OPERATIONS MANAGEMENT OFFICE

ENGINEERING AND OPERATIONS OFFICE

SOMO Technology

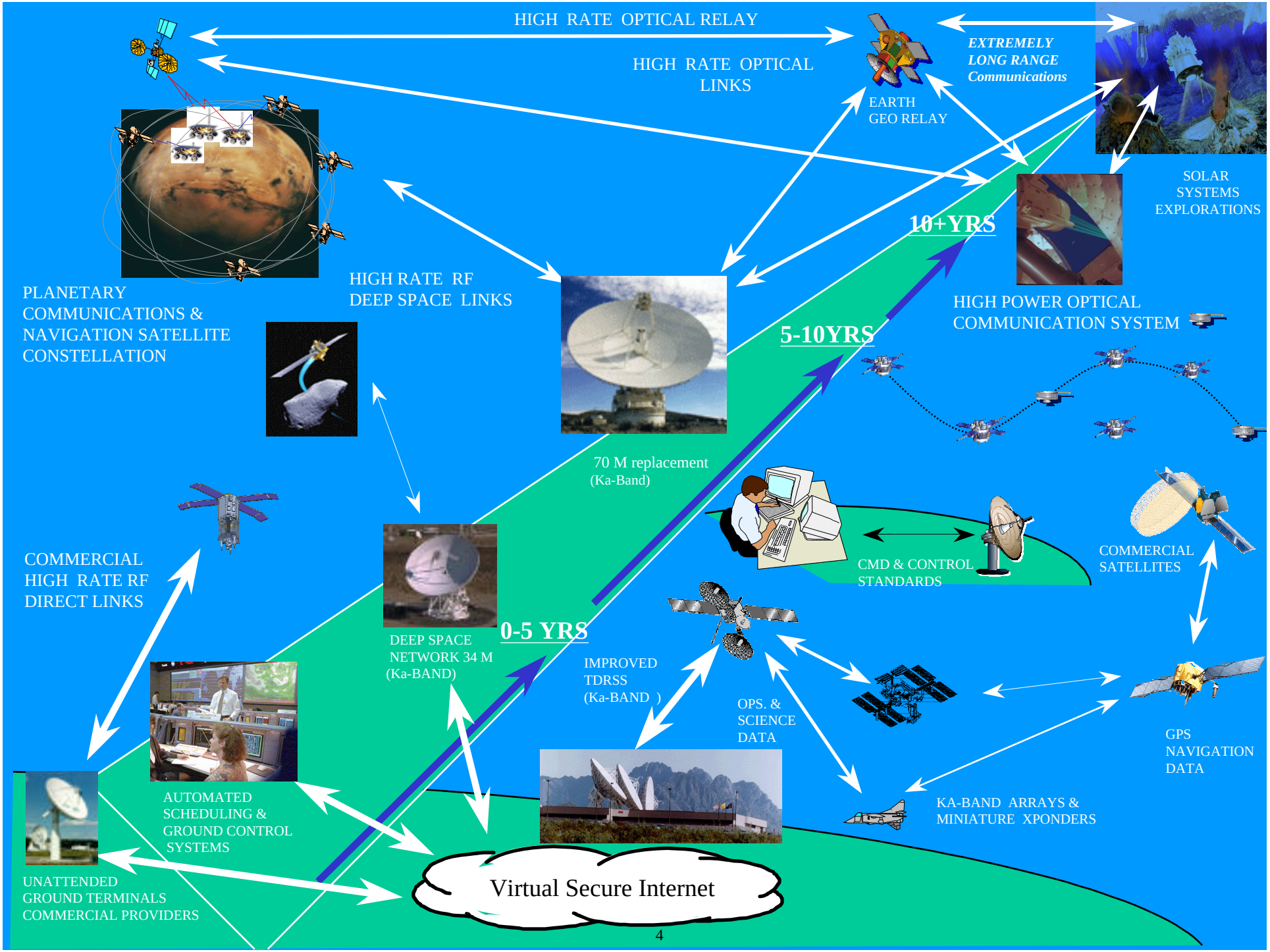
TE/Tom Costello

- Integrated Operations Architecture (IOA) Evolution
  - Integrates all the Space Operations Services
  - Responsive to Customer Needs
  - Provides framework for
    - Technology Projects
    - Mission and Data Services Upgrades Projects
    - Commercialization

- Communications Technology Project
  - Plan Overview
  - Organizational Overview
  - Campaigns

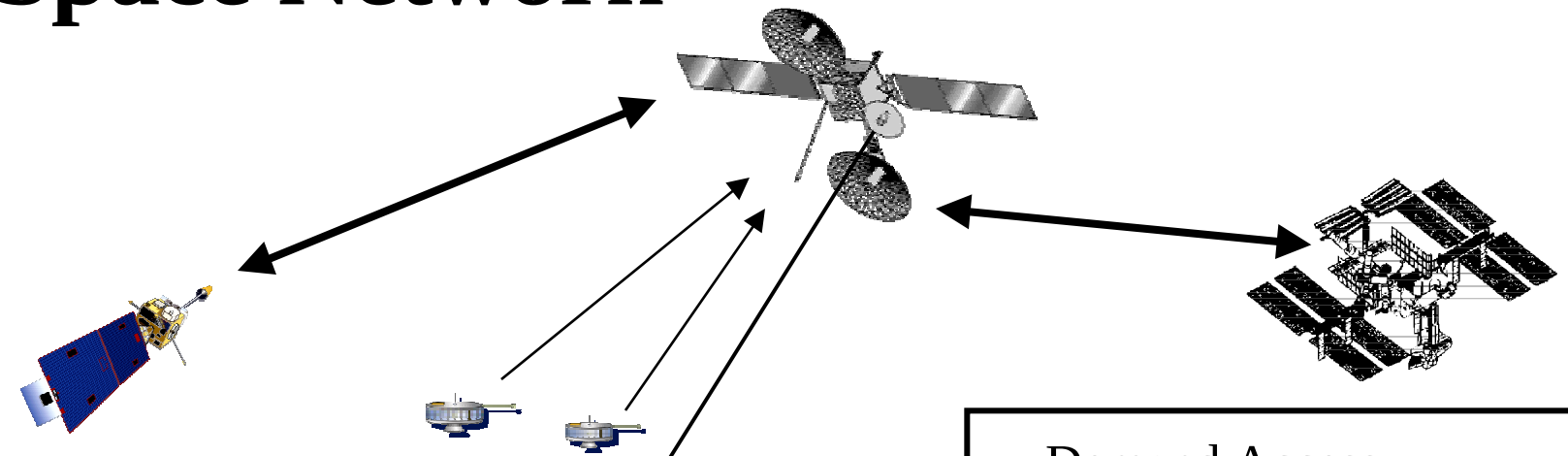
Space Operations Goals/Architecture Drivers

- **Provide space operations services that are responsive to customer missions at the lowest cost to the agency**
  - Advanced communications utilizing high bandwidth demand access systems
  - Efficient constellation operational capabilities
  - Increase automation (ground and on-board spacecraft)
  - Demand driven service
  - Distributed execution
- **Transition operations to commercialized services**
  - Integration of all operations services
  - Consolidated/simplified planning
  - Standards
- **Restructure management & operations processes using concept of customer / service provider**
  - Consolidation and streamlining of services


HIGH RATE OPTICAL RELAY
HIGH RATE OPTICAL LINKS
EARTH GEO RELAY
EXTREMELY LONG RANGE Communications
SOLAR SYSTEMS EXPLORATIONS
10+YRS
PLANETARY COMMUNICATIONS & NAVIGATION SATELLITE CONSTELLATION
HIGH RATE RF DEEP SPACE LINKS
70 M replacement (Ka-Band)
5-10YRS
HIGH POWER OPTICAL COMMUNICATION SYSTEM
COMMERCIAL HIGH RATE RF DIRECT LINKS
DEEP SPACE NETWORK 34 M (Ka-BAND)
0-5 YRS
CMD & CONTROL STANDARDS
COMMERCIAL SATELLITES
IMPROVED TDRSS (Ka-BAND)
OPS. & SCIENCE DATA
GPS NAVIGATION DATA
AUTOMATED SCHEDULING & GROUND CONTROL SYSTEMS
KA-BAND ARRAYS & MINIATURE XPONDERS
UNATTENDED GROUND TERMINALS COMMERCIAL PROVIDERS
Virtual Secure Internet

Space Network

2000 - 2005



- Demand Access
  - Continuous Return Link
- Ka - Band IF Service
  - Intermediate Frequency
- 150 Mbps Space and Ground

Ground Network

Space Network

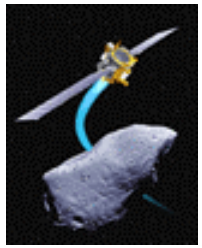
User Community

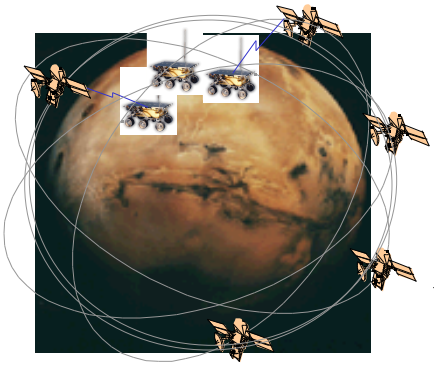
NISN

Deep Space Network

Deep Space Network

2000 - 2005





- Ka downlink on 34 m BWGs
- Turbo coding
- Initial Mars Network

Ground Network

Space Network

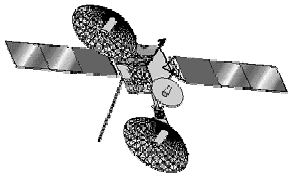
User Community

NISN

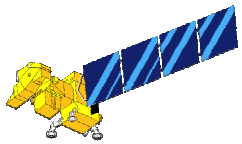
Deep Space Network

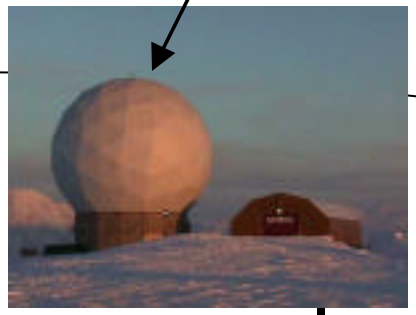
Ground Network

2000 - 2005

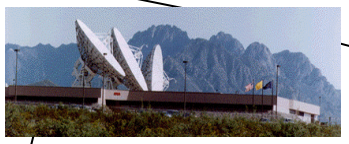


- Commercial Service Providers
- Ka-Band compatibility with SN
- GN compatible commanding added to SN





Ground Network



Space Network

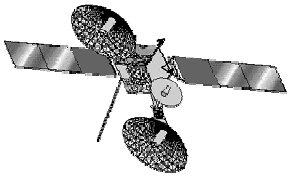
User Community

NISN

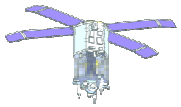
Deep Space Network

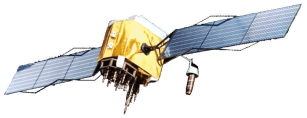
Mission Services

2000 - 2005

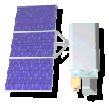


- Consolidated Scheduling at DSMC
- Lights Dim for robotic missions
- On-board GN&C using GPS





GPS Based Navigation



Space Network

User Community

Ground Network

NISN

Deep Space Network

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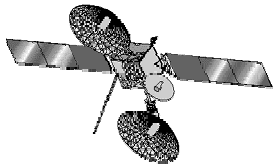
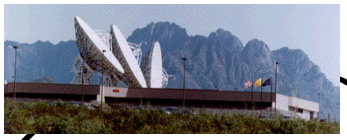
2000 - 2005



Space Network

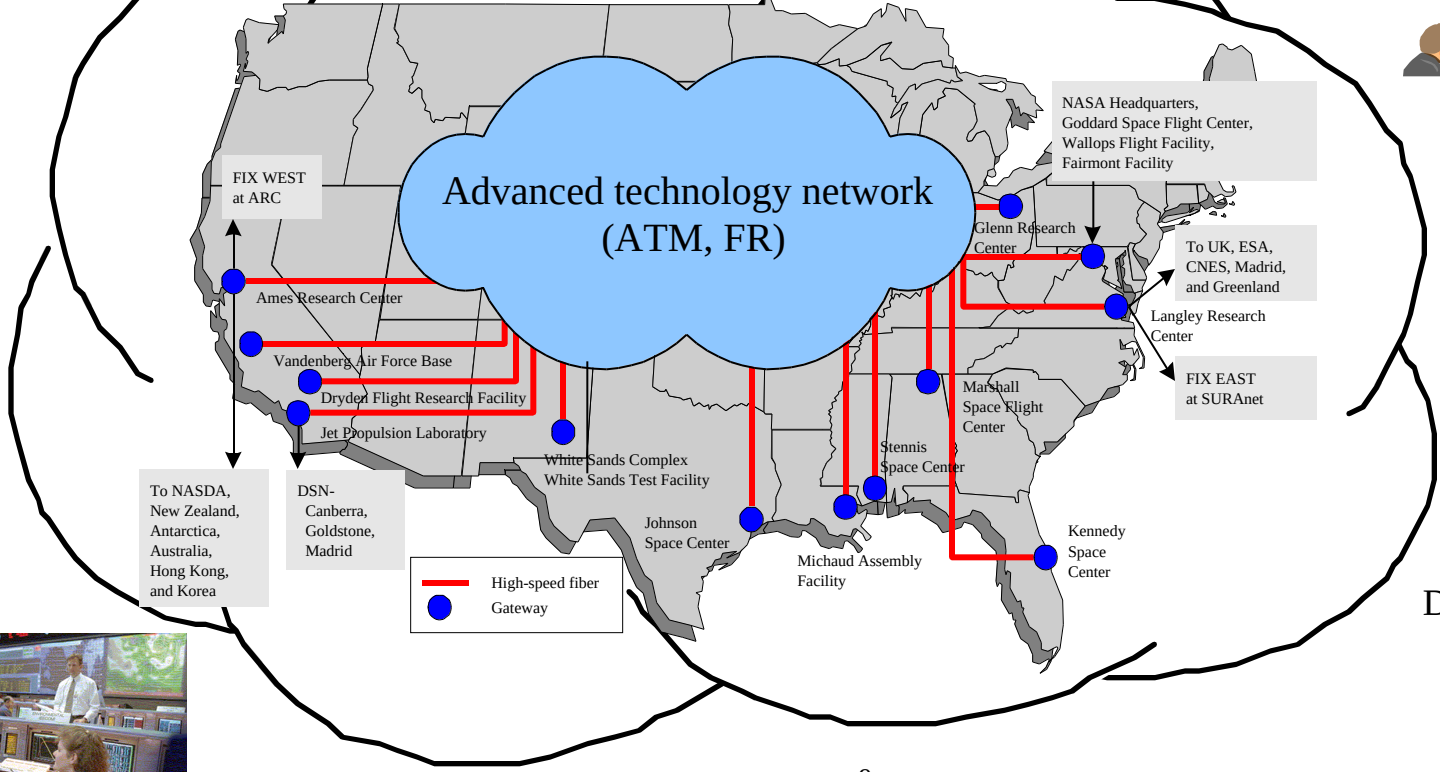
Virtual Secure Internet

- Broadband on Demand
- Quality of Service
- Multimedia streaming



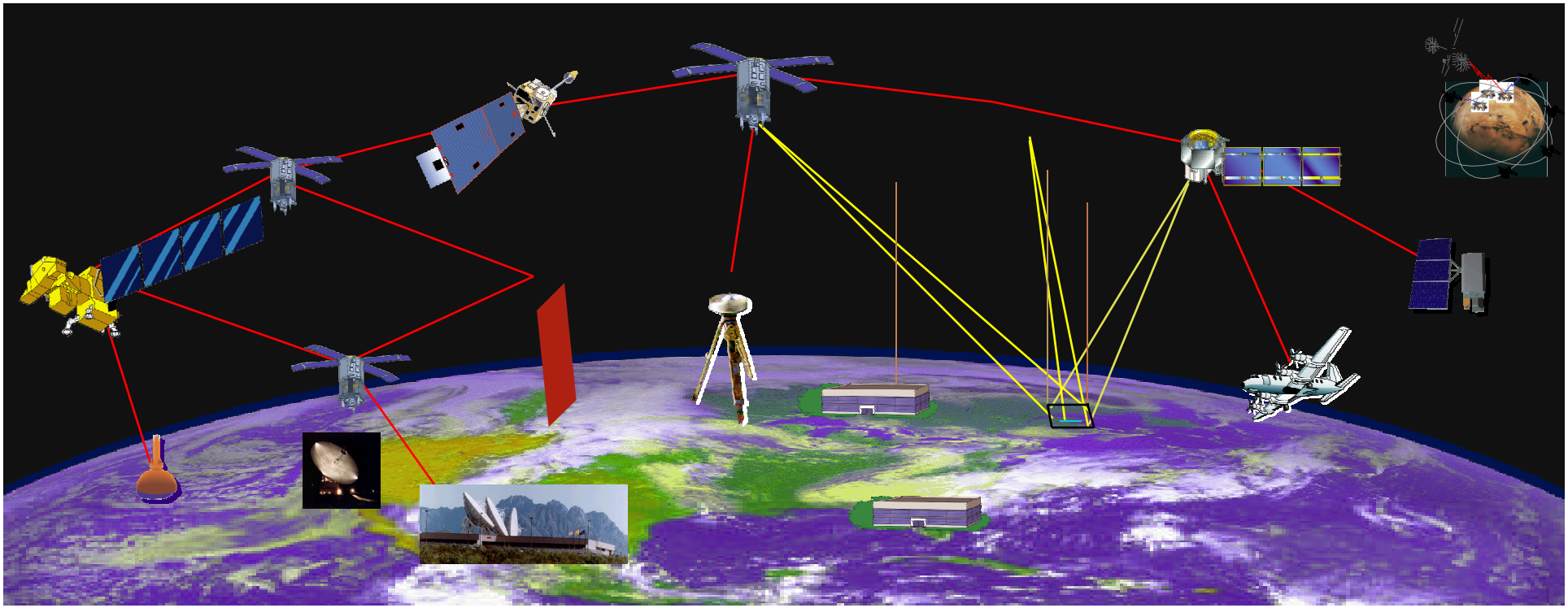
Ground Network

User Community



Deep Space Network

2005 - 2010



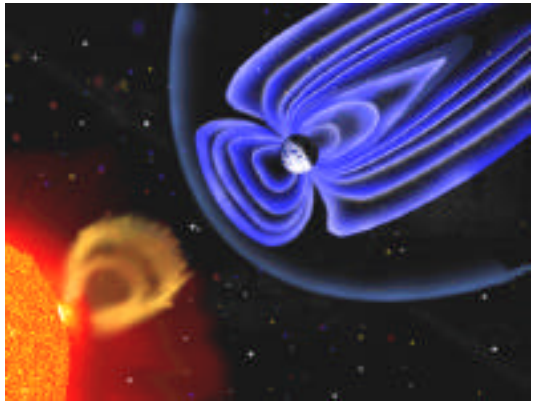
Near Earth Architecture Driven by:

- Constellation of 5-10 spacecraft
  - Goal driven commanding
  - Beacon operations
  - Synchronizing operations
- High Data Rates (600 Mbps - 1Gbps)
- Web based TT&C standards
- Space Internet/PI driven
- Virtual Space Presence

Deep Space Architecture Driven by:

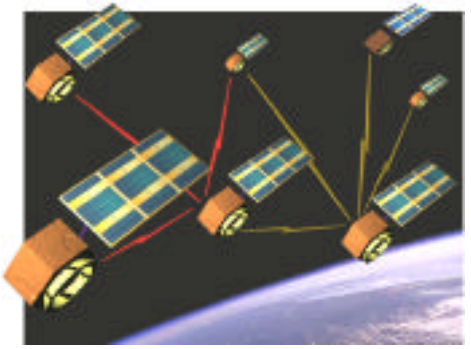
- Return rates of 1-10 Gb/day
  - Continuous video from robotic outpost
  - One full resolution panorama per hour
- Deployed Ka 3m inflatable antenna
- Autonomous navigation service
- Mars Aerostationary Relay

2010+



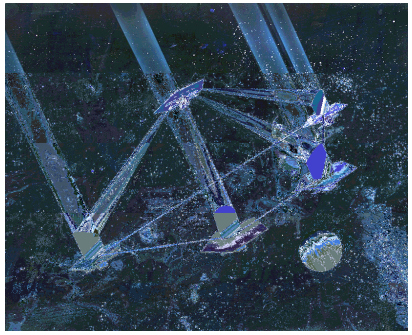
Large Constellations of Spacecraft

Optical Communications for Neptune

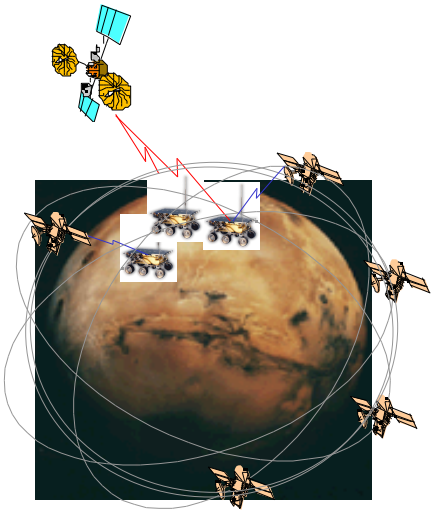


Optical/Ka-band Cross- links, Mission Autonomy

- Dynamic Link Allocation (roaming services)
- Fully autonomous operations
- 70m replacement
- TDRS End-of-Life (EOL)



Virtual Platforms & Constellations



Interplanetary Internet Architectures

Communications Technology Plan Overview

- Identify, develop, integrate, validate, and transfer/infuse advanced technologies that
  - increase the performance,
  - provide new capabilities associated with the IOA Evolution,
  - reduce the costs

  of providing data and mission services to the Space Operations customers

- Campaigns
  - Advanced Communications
  - Space Internet
  - Virtual Space Presence
  - Autonomous Mission Operations
  - Advanced Guidance, Navigation, and Control
- Centers TWG members
  - GSFC/Bob Savage
  - JPL/Jim Lesh
  - GRC/Jim Budinger
  - MSFC/Kathy Hatley
  - ARC/KSC/JSC have not participated, but looking to add participation

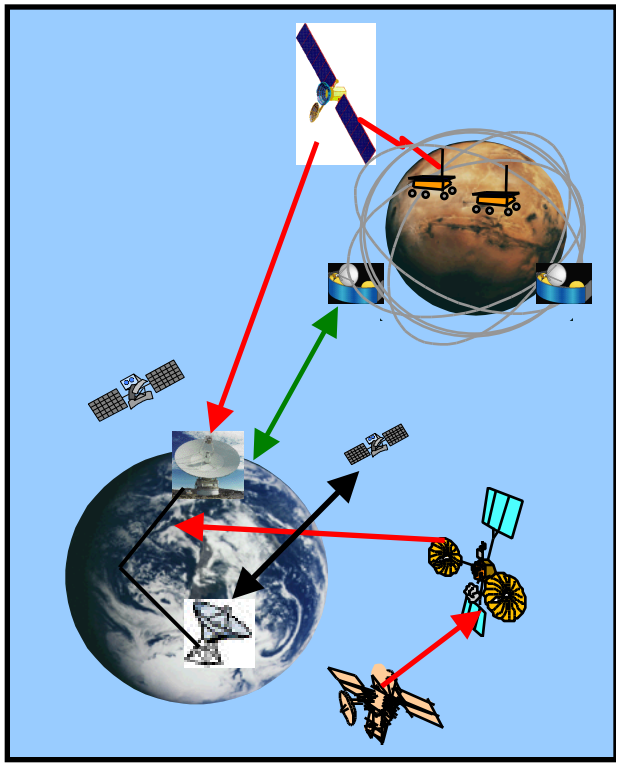
Advanced Communication Campaign

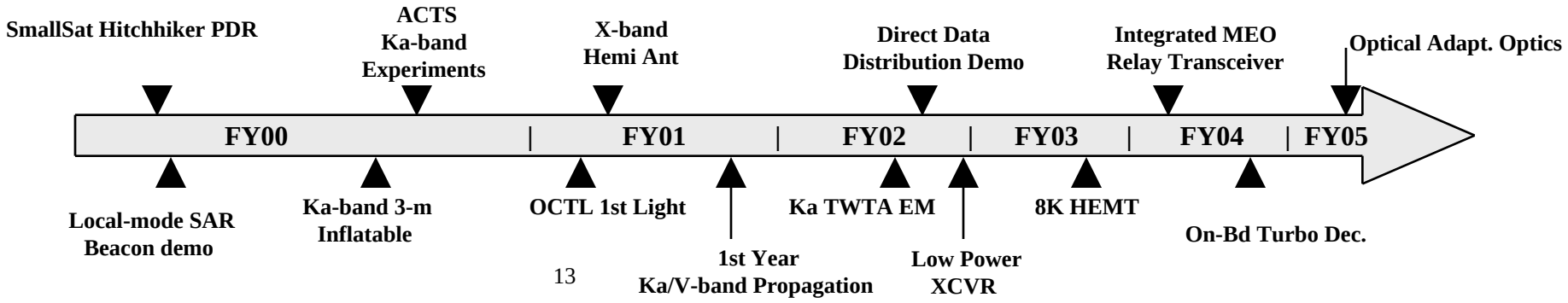
Overall Objective

- Identify, develop, and infuse advanced technologies that will increase NASA space communications capabilities, enable new seamless interoperable communications architectures, and decrease costs of NASA data services.

Products

- Ka-band and Optical communications for high-data rates and/or long-distance missions.
- Agile beam and multi-beam phased array antennas.
- Coding/decoding and compression systems to maximize channel efficiency.
- Low-cost, size, weight, and DC power components (transceivers, modems, solid state amplifiers, etc.)
- Demand access capability





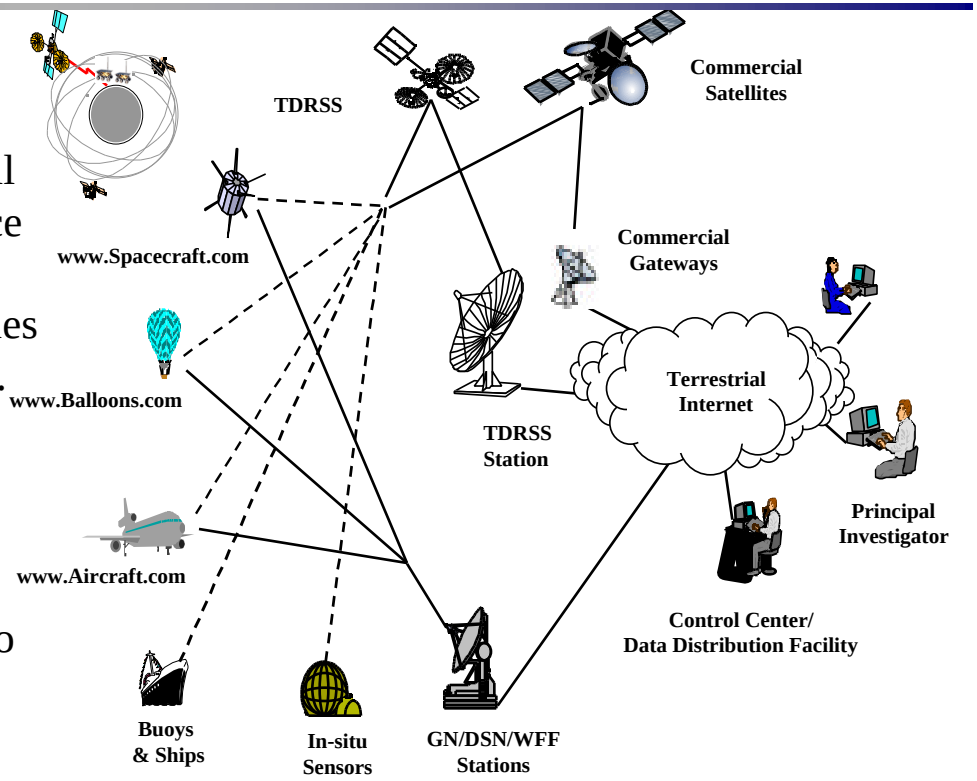
Space Internet Campaign

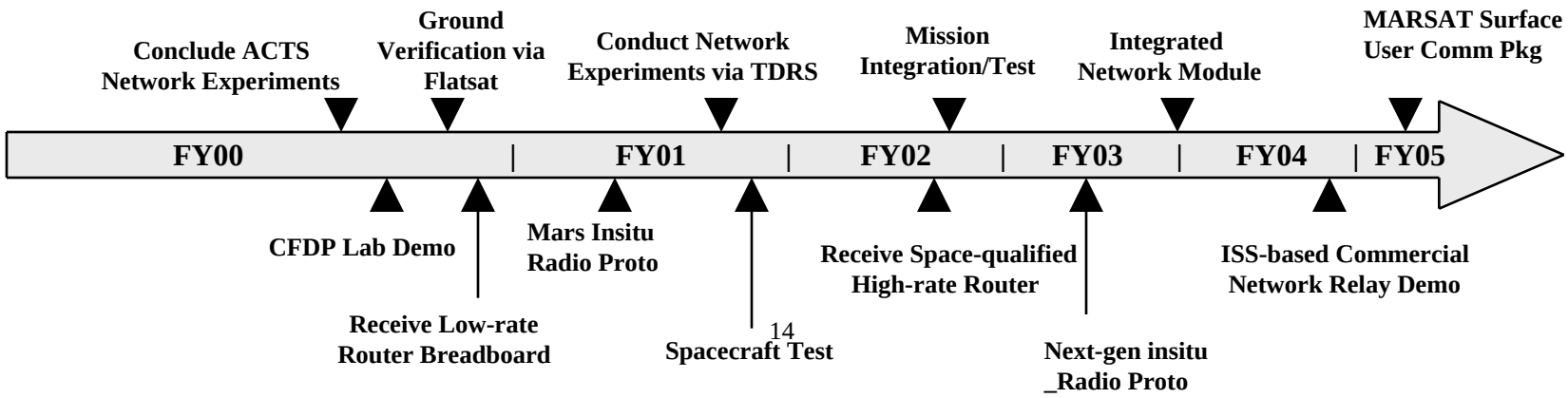
Overall Objective

- Develop, test and demonstrate technologies that will extend the internet paradigm to include NASA space missions enabling the Space Operations vision for transparent operations, and enhancing the capabilities for remote access and control of space-based assets.

Products

- Network architectures to enable the use of the Internet for all future NASA missions
- Routers and LAN's for spacecraft systems.
- Highly-efficient packet and file protocols tailored to the long and variable delays of space link propagation.





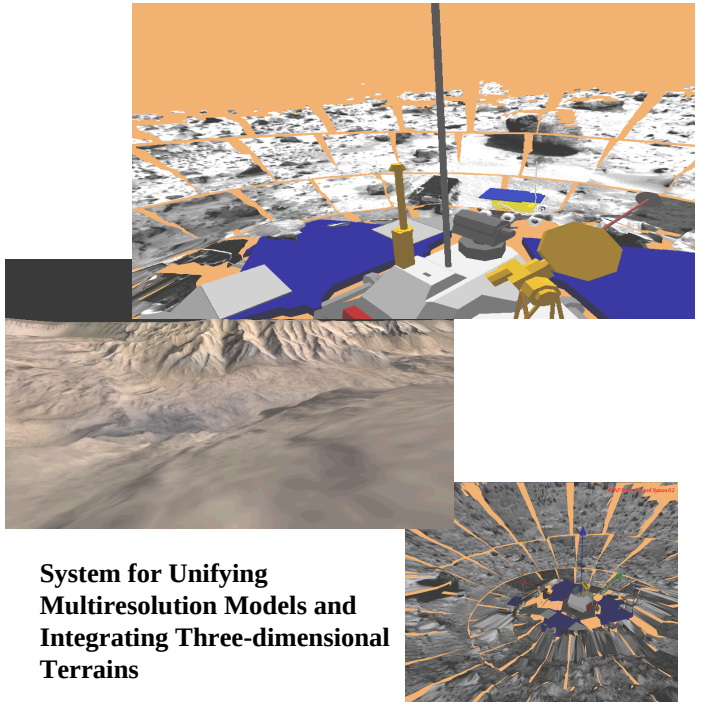
Virtual Space Presence Campaign

Overall Objective

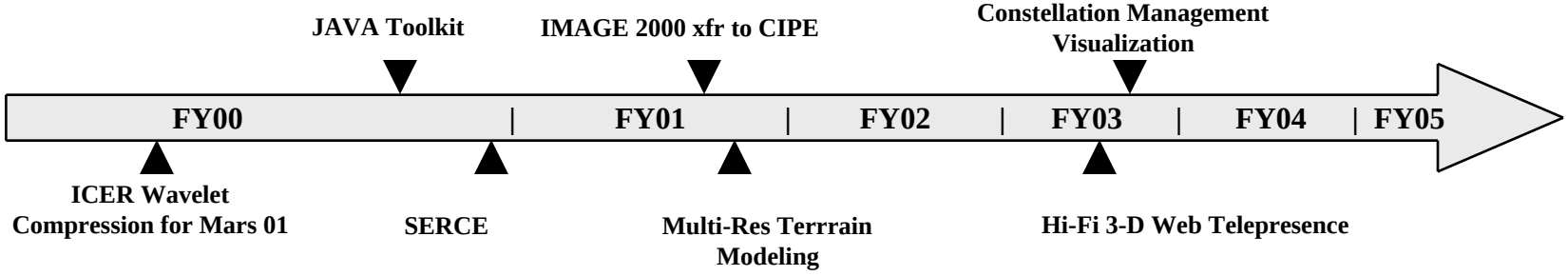
- To enable operators and scientific investigators to more meaningfully visualize data products, and to allow translation of those products into formats that allow the public to experience the excitement of space exploration.

Products

- Tools for high fidelity 3D visualization of planned and executed spacecraft activities.
- System to remotely plan activities and display results which includes controlled access to science data and information.
- Data compression tools and Buffer management strategies to allow maximum scientific data return
- Systems to visualize imaging and non-imaging products



System for Unifying Multiresolution Models and Integrating Three-dimensional Terrains

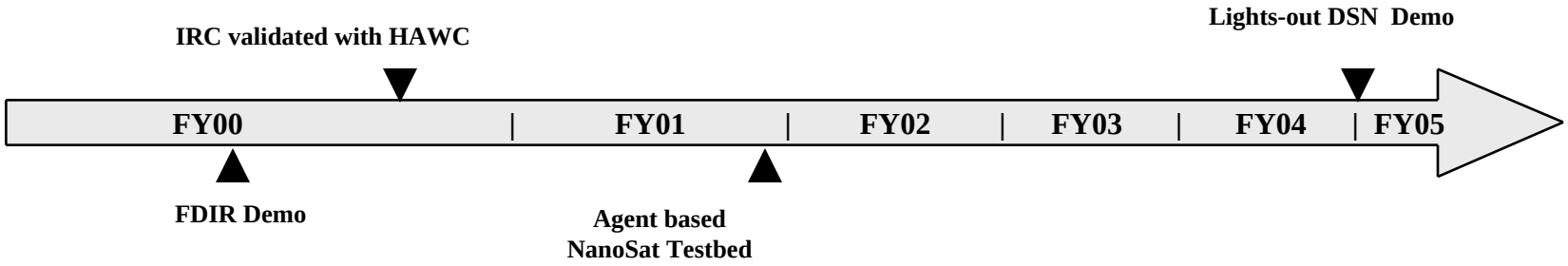


Autonomous Mission Operations Campaign

Overall Objective

- Enable the planning, design, development, and operation of challenging observational or exploration missions with reduced human involvement.
- Products
- Systems for autonomous decision-making and control
  - •Complex navigation and guidance scenarios,
  - •Increase information handling and effective science return,
  - •Collaborative robotic exploration of remote bodies or terrain,
  - •Observations planning and optimization of information return,
  - • Hazard avoidance and autonomous maintenance of S/C.
- Testing techniques for autonomous systems.
- Model-based system design and operations monitoring
- End -to-end goal-oriented planning, commanding, and reporting

Beacon Mode Operations for DS-1



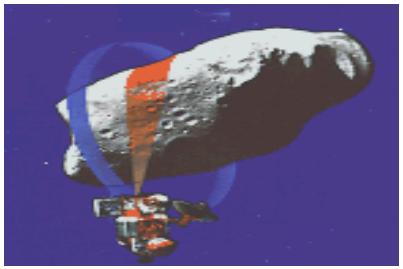
Advanced Guidance, Navigation, and Control Campaign

Overall Objective

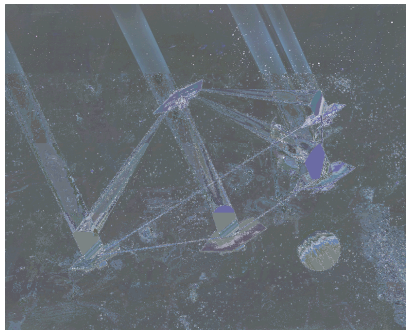
- Improve guidance, navigation and control accuracies, and enable new trajectories and architectures for future challenging missions

Products

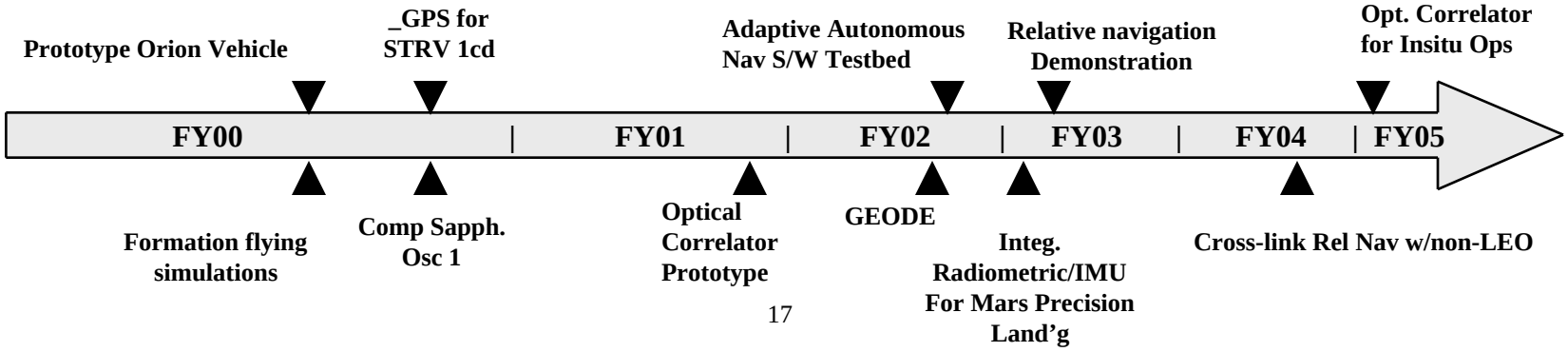
- Techniques for precision landing
- Measurement and control systems to establish and maintain configuration and orientation of formation flying networks
- Rendezvous and docking techniques
- Orbit and landing techniques for small and irregular body targets
- Aerobraking and aerocapture techniques
- Trajectory and orbit calculation tools and visualization techniques for unstable libration points.
- GPS-based techniques to support autonomous navigation for non-LEO missions



Landing on Small Bodies

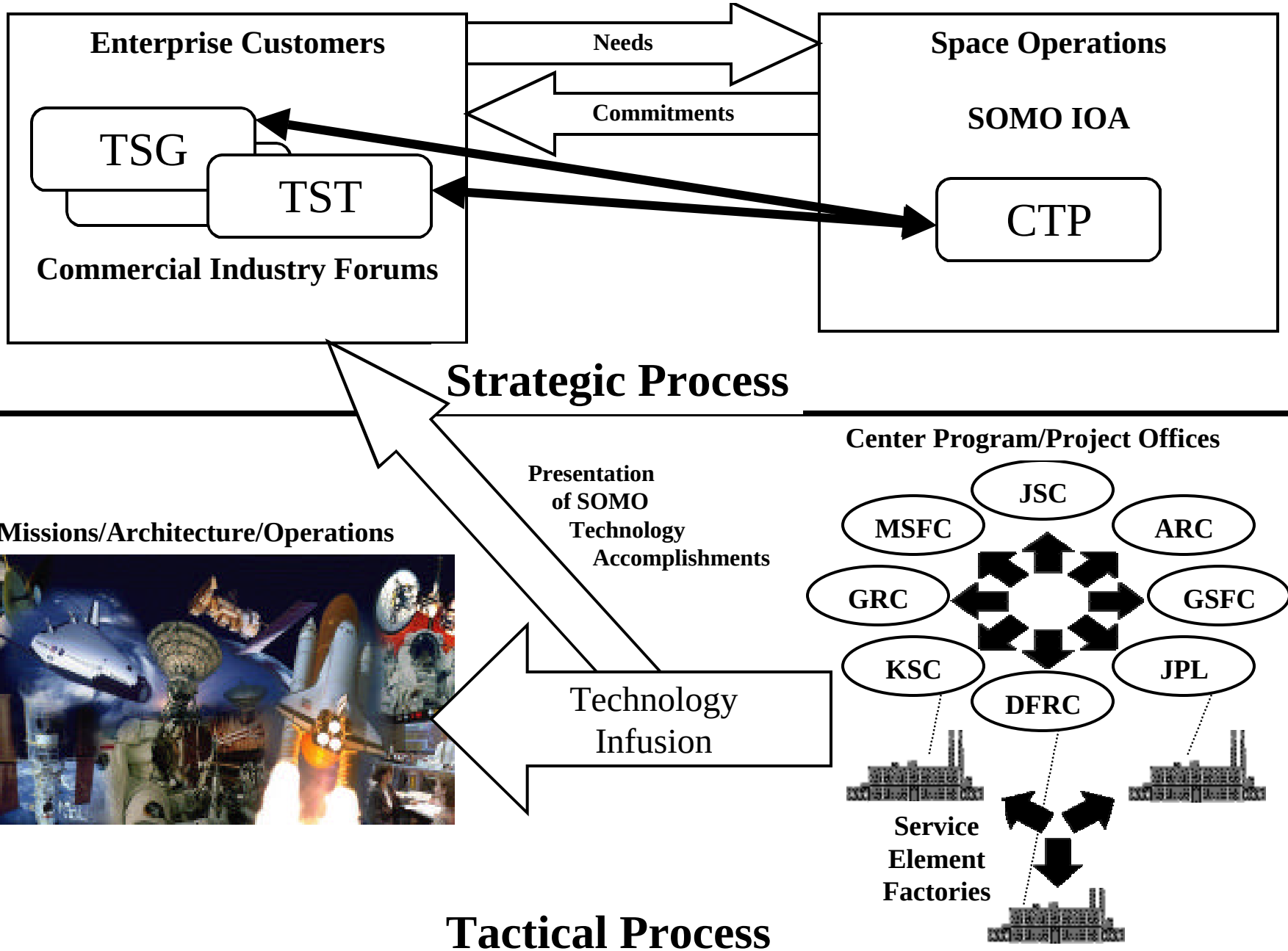


Formation Flying Constellations

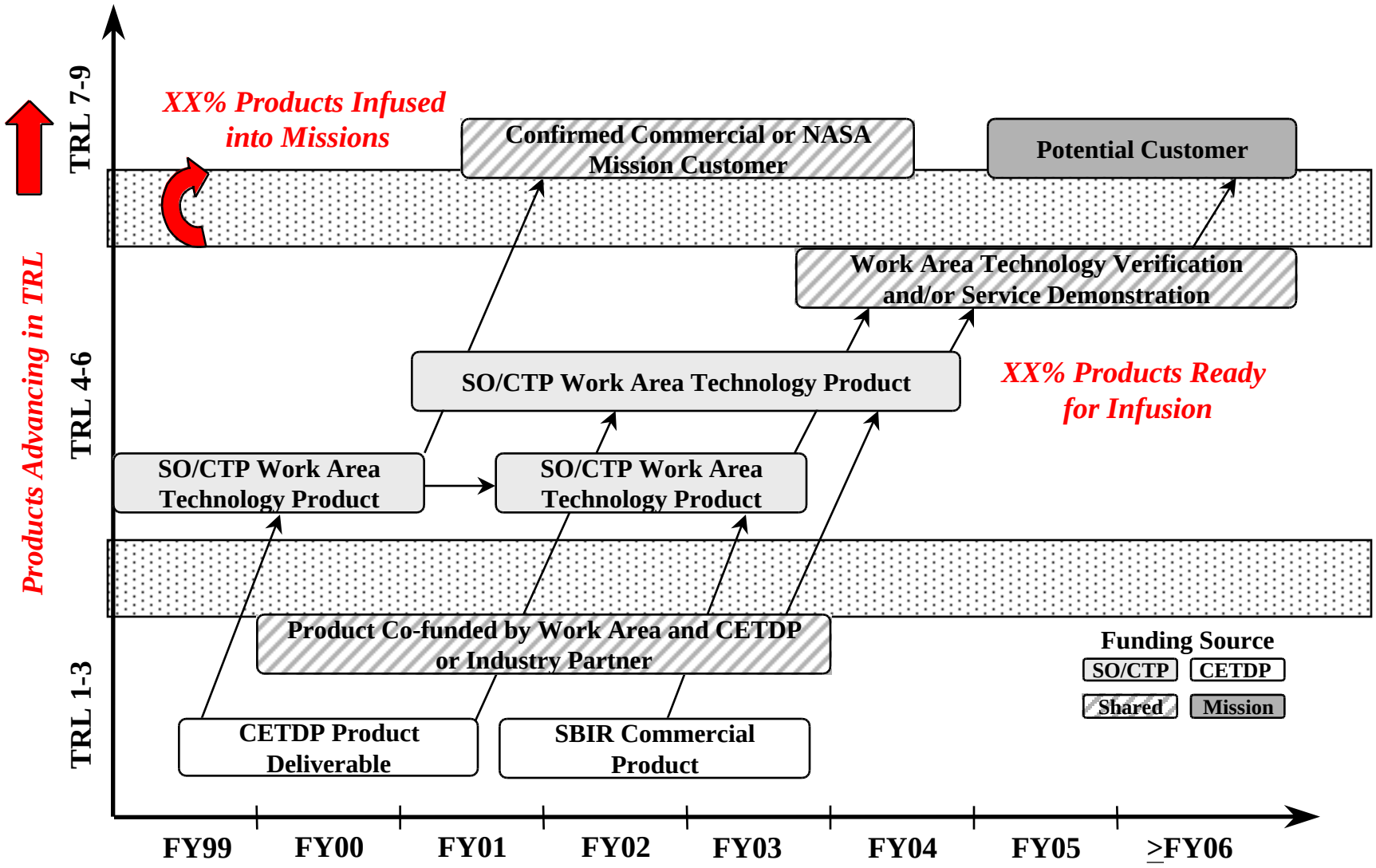


Linkage with Other Agency Programs

Linkage to Other Technology Efforts



Technology Infusion Ladder



Conclusion

- Described the Space Operations Architecture
  - Integrates all the Space Operations Services
  - Responsive to Customer Needs
- Described the Communications Technology Project
  - Responsive to Customer Needs
  - Advanced Communications
  - Space Internet
  - Virtual Space Presence
  - Autonomous Mission Operations
  - Advanced Guidance, Navigation, and Control
- Explained the Linkage to Other Technology Efforts
  - SOMO/Enterprise strategic interfaces
  - Center tactical interfaces
- The role of the Communications Technology Project is to fill the mid-TRL gap between the Cross Enterprise and Mission Specific Programs

Back Up

Advanced Communications Campaign		center	FY00	Work Area
	Local-mode SAR Beacon demo	GSFC	FY00	Search and Rescue Technology Development
	Local-mode Search And Rescue (SAR) Beacon demonstration			
	SmallSat Hitchhiker PDR	GSFC	FY00	Adv Modulation, coding, Proc and compression
	Small Satellite Optical Communications Hitchhiker Payload Design Review			
	Ka-band 3-m inflatable	JPL	FY00	Spacecraft Radio Systems
	Ka-band (DSN) 3 meter inflatable reflect array rev B breadboard			
	ACTS Ka-band Experiments	GRC	FY00	System Analysis & Technology Studies
	Complete all Advanced Communications Technology Satellite Ka-band experiments			
	OCTL 1st Light	JPL	FY01	Optical Communication
	Optical Communications Technology Laboratory (OCTL) initial transmission capability			
	X-band Hemi Ant	GSFC	FY01	Adv Comm Terminals for ES and SS
	X-band, Hemispherical coverage antenna			
	1st Year Ka/V-band Propagation	GRC	FY01	System Analysis & Technology Studies
	Complete first year of statistical investigations of system availability at Ka and V band using an ESA provided beacon			
	Ka TWTA EM	JPL	FY02	Spacecraft Radio Systems
	DSN spacecraft Traveling Wave Tube Amplifier (TWTA) Engineering Model			
	Direct Data Distribution Demo	GRC	FY02	Direct Data Distribution
	Shuttle flight demonstration of 1 GBPS link direct to ground station			
	Low Power XCVR	GSFC	FY02	Adv Comm Terminals for ES and SS
	Low Power Transceiver Flight unit available			
	8K HEMT	JPL	FY03	Ground Antenna Systems
	High Electron Mobility Transistor (HEMT) Low Noise Amplifier (LNA) exceeding 10 K noise temperature performance			
	Integrated MEO Relay Transceiver	GRC	FY04	Integrated Communications Technologies
	Integrated Medium Earth Orbit relay transceiver			
	On-Bd Turbo Dec.	JPL	FY04	Communication Systems Analysis
	Spacecraft based turbo decoding			
	Optical Adapt. Optics	JPL	FY05	Optical Communication
	Optical Adaptive Optics augmentation to OCTL			

Space Internet Campaign				
	Conclude ACTS Network Experiments	GRC	FY00	Technologies for Space Internet Services (Tsis)
	Complete Advanced Communications Technology Satellite Networking Experiments			
	CFDP Lab Demo	JPL	FY00	Infrastructure and Automation
	CCSDS [Consultative Committee for Space Data Systems] File Delivery Protocol (CFDP) lab demonstration			
	Ground Verification via Flatsat	GSFC	FY00	Spacecraft as an Internet Node
	Build and Demonstrate near-flight-quality Internet Protocol mission in the lab ("Flatsat")			
	Receive Low-rate Router Breadboard	GRC	FY00	Technologies for Space Internet Services (Tsis)
	Breadboard leading to router on a chip in the <10 MBps data rate			
	Mars insitu Radio Proto	JPL	FY01	In Situ Comm & Nav Systems
	Prototype for Mars insitu radio			
	Conduct Network Experiments via TDRS	GRC	FY01	Technologies for Space Internet Services (Tsis)
	Continue the class of experimentation currently performed on ACTS via TDRS, preferably H			
	Receive Space-qualified High-rate Router	GRC	FY02	Technologies for Space Internet Services (Tsis)
	Receive delivery of a 100MBps class space-qualified router			
	Mission Integration/Test	GSFC	FY02	Spacecraft as an Internet Node
	Capability to integrate and test with a "real" mission Internet Protocols			
	Next-gen insitu	JPL	FY03	In Situ Comm & Nav Systems
	Next-generation insitu micro-radio prototype			
	Integrated Network Module	GRC	FY03	Technologies for Space Internet Services (Tsis)
	Integrated network module combining network interface, LAN interface, and router interface into a single module			
	ISS-based Commercial network Relay Demo	GRC	FY04	Technologies for Space Internet Services (Tsis)
	demonstrate on International Space Station commercial network based relay technology			
	MarSat Surface User Comm Pkg	JPL	FY05	In Situ Comm & Nav Systems
	Mars user interface to the MarSat relay satellite			

Virtual Space Presence Campaign				
	ICER Wavelet Compression for Mars 01	JPL	FY00	Science Processing and Information Management
	ICER (Adaptive Wavelet Compression) transfer to Mars '01			
	JAVA Toolkit	JPL	FY00	Science Processing and Information Management
	JAVA Toolkit for visualization			
	SERCE	GSFC	FY00	User Tools for Autonomous Systems
	Spacecraft Emergency Response System (SERS) Collaborative Environment			
	IMAGE 2000 xfr to CIPE	GSFC	FY01	User Tools for Autonomous Systems
	transfer to the Center for Image Processing in Education (CIPE) a tool using JAVA 2 and JAVA Advanced Imaging			
	Multi-Res Terrain Modeling	JPL	FY01	Science Processing and Information Management
	System for Unifying Multiresolution Models and Integrating Three-dimensional Terrains			
	Constellation Management Visualization	GSFC	FY03	User Tools for Autonomous Systems
	Visualization tools supporting constellation management			
	Hi-Fi 3-D Web Telepresence	JPL	FY03	Science Processing and Information Management
	Hi-Fidelity, 3-D Web Telepresence			

Autonomous Mission Operations Campaign				
	FDIR Demo	JPL	FY00	Infrastructure and Automation
	Demonstration of Fault, Detection, Isolation, and Recovery (FDIR) server during real-time DSN operations			
	IRC validated with HAWC	GSFC	FY00	End-to-End Mission Autonomy
	Instrument Remote Control (IRC) delivered to High Resolution Airborne Wideband Camera (HAWC)			
	Agent-based NanoSat Testbed	GSFC	FY01	
	Thermal and Power subsystems are the first components for the virtual NanoSat testbed			
	Lights-out DSN Demo	JPL	FY05	Infrastructure and Automation
	Lights-out (no on duty operators) DSN Demonstration			

Advanced Guidance, Navigation, and Control Campaign				
	Formation flying simulations	GSFC	FY00	Flight Dynamics Technologies
	Create initial version of formation flying testbed that includes GPS simulation capabilities.			
	Prototype Orion Vehicle	GSFC	FY00	Flight Dynamics Technologies
	Implement prototye Orion vehicle to fly in conjunction with Air Force Research lab MightySat 11.2 and Orion Jr.			
	Comp Sapph. Osc 1	JPL	FY00	Frequency and Timing
	Compensated Sapphire Oscillat+B102or with closed-cycle cooler for improved operability			
		JPL	FY00	Navigation and Radio Metrics
	Deliver STRV micro GPS space flight instrument to DERA, U.K.			
	Optical Correlator Prototype	JPL	FY01	Navigation and Radio Metrics
	512x512 grayscale optical correlator for real-time landmark tracking			
	Adaptive Autonomous Nav S/W Testbed	JPL	FY02	Navigation and Radio Metrics
	Adaptive Autonomous Navigation SoftWare Testbed			
	GEODE	GSFC	FY02	Flight Dynamics Technologies
	GPS Enhanced Orbit Determination Experiment (GEODE) flight code			
	Integ. Radiometric/IMU For Mars Precision Land	JPL	FY03	Navigation and Radio Metrics
	Integrated radiometric and inertial measurement unit for Mars precision landing			
	Cross-link Rel Nav w/non-LEO Formation	GSFC	FY04	Flight Dynamics Technologies
	Develop modified cross-link relative navigation for non-Leo missions (High Earth Orbit (HEO, Liberation point, etc.)			
	Opt. Correlator for Insitu Ops	JPL	FY05	Navigation and Radio Metrics
	Optical correlator for insitu operations			

SOMO Technology Project Customer Relevance

Campaigns / Work Areas	Space Science								Earth Sciecne				HEDS				Other	
Advanced Communications																		
Advanced Modulation, Coding, Processing, and Compression	X		P	P	X	P	P	X	P	P					P	P	P	
Search and Rescue Technology Development													X	X		P		
Advanced Communication Terminals for Earth and Space Science	X		P	P	X	P	P	X	P	P					P	P	P	
Ground Antenna Systems	X	P	P	P	P	P	P					X	P			P	X	
Communications Systems Analysis	X	P	P	P	P	P	P		X		X	X	P	X	X	P	X	X
Spacecraft Radio Systems	X	P	P	P	P	P	P		X		X	X	P	X	X	P	X	X
Optical Comm	X	P	P	P	P	P	P		X		X	X	P	P		P	X	X
Advanced Concepts Development	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	P		P
Direct Data Distribution (D3)	X	X	P	P	P	X	X	X	P	P	P	X	X	P	P	P	P	P
Integrated Communication Technologies	X	X	P	P	P	X	X	X	P	P	P	X	X	P	P	P	X	P
Networks	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		X
Space Internet																		
Spacecraft as an Internet Node						P	X					X		P	P	P		
Infrastructure and Automation	P	P	P	P	P	P	P					X	P	X		P	X	X
In Situ Comm/Nav	X	P			P	P	P				X	X	P	P		P	X	X
Technologies for Space Internet Services	X	X	X	X	X	P	P	P	P	P	P	P	X	P	P	P	X	P
Virtual Space Presence																		
User Interface for Autonomous Systems	P		P	P	P	P	P		P	P	P					P	P	
Science Processing and Info Mgmt	P	P	P	P	P	P	P		X		X	X	P	X		P	X	X
Autonomous Mission Operations																		
Auton Ground Network & Mission Ops Center Systems	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Infrastructure and Automation	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Advanced Guidance, Navigation & Control																		
Autonomous Constellation Control and Formation Flying	P		P	P	P	P	P	X	P	X				P	P	P	P	
Navigation and Radio Metrics	P	P	P	X	P	P	P		X		X	X	P	X	X	P	X	X
Frequency and Timing	X	P	P	X	X	X	X		X		X	X	X	X	X	P	P	P

P Primary Technology Driver **X** Technology Benefits